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warmth we were most successful with Dimmick's electric stimulator. Our procedure was as follows. We first isolated warm spots which had a hair within their area or very near them. Then, in an experiment, we first aroused warmth; and when it was reported, raised the hair. Under these conditions we obtained a perception in 7 of 11 trials with *H*, in 5 of 24 with *S*, and in 1 of 35 trials with *A*. The naming of the perception was found to be much more difficult than in the areal experiments. Typical reports are: (*H*) "Qualitatively, I do not see much difference between this semi-liquid and the one my finger was in;" "I get the warmth and pressure beaten up in perception, it was oily in quality;" "the experience is like a drop of dense liquid; it is not wet; I don't know what to call it; it is a little like dense mercury, and a little like a heavy oil;" (*S*) "It is oily rather than wet;" "when the warmth and pressure are nearly equal I get the perception of oiliness;" "it feels a little like warm butter on the end of a toothpick. The perception does not come easily; it is hard to name it." The one perception of *A* was: "It feels sticky, like grease."

Psychologically, the experience is nearly always a warmish pressure; it is a fusion in the sense that it is unitary and yet may at any time be analysed into the two qualities. In the integration the pressure, which must be steady and not too intensive, seems to spread a little and to lose its sharpness of definition.

Conclusions. Our results appear to explain the divergence noted at the outset of this Study. There can be no doubt that the warmth-pressure integration, if it suggests an object of perception at all, most often and most naturally carries the meaning of oiliness. If, then, the *Os* are set for a one-to-one correlation of experience and perceptive meaning (and this set may be induced without any corresponding instruction from *E*), they will give a regular report of 'oily' in the synthetic experiment. In so far we agree with Cobbey and Sullivan.

But oiliness is not, under ordinary circumstances, a sheerly cutaneous perception. If, then, the *Os* are not set for perceptive report, the word 'oiliness' need never occur to them; and if they are set for perception generically only, and not specifically, they may vary in their reports,—they may fail to discover an appropriate term, or they may interchange 'oil' with such other substances as 'butter' and 'glue' and 'molasses,' or they may settle easily upon the single word 'oily.' In this way we account for the results of Malmud and for those of our present observers.

It seems, therefore, more nearly true to say that the integration of pressure and warmth is a compulsory part-condition of the perception of oiliness than to regard it as the single adequate condition.

LXII. THE INTEGRATION OF WARMTH AND PAIN

By LUCILE KNIGHT

This study forms a member of a series undertaken to discover what results psychologically when warm, cold, pressure, and pain spots are taken in pairs and stimulated simultaneously.¹ In this investigation we have worked with warm and pain spots.

¹For references to the earlier investigations, see R. S. Malmud, this JOURNAL, xxxii, 1921, 571. See also J. H. Alston, *ib.*, xxxi, 1920, 303; and L. W. Cobbey and A. H. Sullivan, *ib.*, xxxiii, 1922, 121.

Before beginning the experiment proper we practised the technique of localization and stimulation of pain spots, and acquainted our *O*s with the qualities of pain. All spots were localized within an area 2 cm. sq., on the volar side of the fore-arm: the skin was first softened with soap and water, and then explored with a sharpened horse-hair 2.5 cm. in length. This stimulus was found to be inadequate to the arousal of pain when the skin was etherized. After two weeks of preliminary work we localized warm and pressure spots within the same area, and selected for experimentation spots that responded with a warmth of good intensity, and that had closely neighboring pain spots. We took particular care that no pressure spot was near enough to be stimulated in any way during the course of an experiment. In a first series of experiments we employed two *O*s, Miss E. Powell (*P*), and Miss E. Davis (*D*), both of whom were specializing in psychology. For the arousal of warm spots we used Dimmick's electrical apparatus, which stimulates the spots by radiant heat. This was so mounted that it could be lowered to a position about 2 mm. from the surface of the skin, and then, when warmth had appeared, could gradually be raised and the warmth still maintained. Our procedure in a single experiment was to arouse warmth; then, when it was reported, to give the signal 'now'; and after 1.5 sec. to stimulate the pain spot (which had been softened with vaseline) with the sharpened hair. The instruction to the *O* was as follows: "You will be given a cutaneous stimulation on the forearm. Report the course of the resulting experience. You may give a running account if you like."

The results obtained by this method were not satisfactory; the heat from the apparatus frequently not only curled and therefore destroyed the hair, but also dried the skin so rapidly that pain spots failed to respond. Both *O*s, however, gave reports which indicated that the conditions of an integration were at times obtained. The two qualities seemed either to form a spatial pattern in which they ran their courses side by side, or to fuse in a new quality which was called 'hotness'. From a study of the reports we felt moderately sure of this fusion; but we could not be certain that the 'hotness' was not occasioned by the radiant heat of our apparatus. *E*, it is true, always raised the apparatus to what she thought was a safe distance; but she had no other guide than the reports of her *O*s. We determined, therefore, upon a test experiment that should more adequately be controlled, and that should be undertaken with more experienced *O*s.

In this second series of experiments we mounted the electrical apparatus on a universal standard and let *O* himself, by turning the screw which raised or lowered the stimulator, control the degree of warmth. We also placed the arm in a plaster cast, took the additional precaution of selecting warmspots that were not contiguous to cold spots, and aroused pain by touching the skin lightly with a needle. The *O*s were Professor Weld (*W*), Professor Hoisington (*H*), and Dr. Bishop (*B*). The author also observed in a few experiments in which Professor Weld served as *E*. *O* was asked to adjust the apparatus until he felt a continuous warmth, and then to say 'now;' the pain stimulus was then applied, and *O* straightway described the resulting experience.

Under these conditions 'burning heat' or 'hotness' was usually reported. In general, the loose, comfortable warmth contracts about a hard penetrating stingy pain; the warmth is replaced by a definitely painful sting (heat). We were able to compare the fusion thus obtained with an actual burn by lowering the apparatus until burn appeared, then raising it until only warmth remained, and then stimulating with the needle. At first all *O*s were unable to distinguish the two experiences, but after a few trials an extensive difference was made out. Typical reports of the *O*s are as follows.

H. "The latter [with the needle] is a little less extended; qualitatively, I don't see any difference;" "a sharp one this time; it was more

limited in extent but quite as penetrating and as burny;" "I called 'now' when the other sting was there, so I had the two together. The sting from the heat was weak, that of the needle more intense and went deeper; qualitatively I could not say which was which. In general, the difference is one in intensity; the one with the needle is usually less extended, although they may be similar in extent; the actual burn is more like several points, but they are not so lively."

W. "The needle-burn was much more pointed, sharper, not so sting-like this time, but smaller and more punctiform. Qualitatively, the two experiences are exactly alike; the difference is areal;" "the warmth was there, a deep diffuse warmth, and then it changed to a warmth centralized, punctiform and more like pain; the change was not sharp or sudden like a typical prick; it was more durative, like an increase in intensity."

B. "Burning warmth again! It differs from the actual burn in that it is brighter, more concentrated, smaller in area. It seems centered in an area of soft warmth, a little hard part that creeps in;" "except for an occasional dull pressure that comes in with the needle prick, the two experiences are qualitatively the same; the sting is less intensive than with full heat, *i. e.*, the burn is not so great."

All *Os* agree that the experience is a fusion, probably of warmth and prick, but it may be of sting (heat) and prick. At times it is a warm painful sting, at others a merely painful sting. In the latter case the warmth seems to become stinging, and this invariable stinging quality makes analysis difficult; it is not easy at times to distinguish it from warmth, and at others from pain. We are accustomed to regard sting as an intermediate quality which results from the simultaneous stimulation of warm and cold spots; but it is reasonably certain that no cold spots were stimulated in the present experiments. We found also that, with continuous stimulation of a warm spot by radiant heat, warmth changes to sting before burn appears; and in a few casual observations we were unable to distinguish this sting from that obtained by the simultaneous stimulation of a warm and a cold spot. The point would seem to be of considerable systematic importance, and we regret that we have been unable for lack of time to pursue it further.⁴

We are convinced, however, that warmth, particularly a warmth of good intensity, is qualitatively much more like sting than Cutolo has led us to suppose.⁵ In our attempt to obtain an analysis of 'burn' we repeatedly asked our *Os* to compare the warmth and sting obtained by radiant heat. Some of the reports follow.

W. "Warmth, particularly at the higher intensities, is much like sting, and a high degree of warmth has the promise of sting. There are times when it is impossible to say when warmth changes to sting. The two qualities are, however, quite different, and the change from the one to the other is quick and smooth."

H. "As warmth got more intensive it became more alive and very weakly stinging. I could find no point where warmth changes to sting;" "there was a change from a rather soft, loose warmth to a more alive, penetrating, slightly stinging quality; I could not tell just where the change takes place; it is almost like a change in intensity;" "warmth itself seems to grow until it gets stinging."

⁴We realize, in particular, that a radiant source, however carefully controlled, must be physiologically suspect. We hope to return to the problem with another technique.

⁵F. Cutolo, Jr., A Preliminary Study of the Psychology of Heat, this JOURNAL, xxix, 1918, 445ff. J. H. Alston, *op. cit.*, 312, gives some evidence for the view that heat is more like cold than warmth.

B. "At first an increase in warmth; then, as soon as warmth reaches a certain intensity, something else, a prickiness or sting, comes in which is more like pain than pressure; I should say that warmth is like pressure on one side and like sting on the other."

Our cases are too few to permit of a generalization; but we think it probable that further observation will place warmth in a pressure-pain continuum between pressure and sting (heat); no one who is familiar with warmth would hesitate to say that it is like pressure, and our *Os* unite in saying that, under our conditions, warmth is also like sting.

Conclusions. (1) The simultaneous stimulation of warm and pain spots may result in an experience which is variously called 'burning heat,' 'burn', and 'hotness'. Psychologically it seems to be a fusion of the prick quality of pain with either warmth or sting. It is best obtained when the warmth is focal and of good intensity, and the pain not too intensive. At similar intensities this fusion differs from 'actual burn' only in extensity.

(2) The continuous stimulation of a warm spot with radiant heat of constant intensity results in a series of qualities from warmth through sting and burn to pain.⁶ The 'sting' obtained in this way is similar to (if not identical with) the quality obtained from the simultaneous stimulation of warm and cold spots, and it was found to have a qualitative likeness to warmth. There is some evidence, therefore, for the statement that warmth lies in a qualitative pressure-pain continuum.

⁶Warmth, sting (heat), and pain we take to be simple qualities, although we are not prepared to name the quality of the final pain.